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COMBINED SCALE WEIGHT, HEIGHT AT HIPS
AND VISUAL CONDITION SCORE AS AN
INDICATOR OF FUNCTIONAL BODY
SIZE IN RANGE COWS

by

Patricia B. Davis

A thesis submitted in partial fulfillment
of the requirements for the degree


of

MASTER OF SCIENCE

in

Animal Science

Approved:



UTAH STATE UNIVERSITY
Logan, Utah

1984

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Patricia B. Davis

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ABSTRACT

Combined Scale Weight, Height at Hips
and Visual Condition Score as an
Indicator of Functional Body
Size in Range Cows
by

Patricia B. Davis, Master of Science
Utah State University, 1984

Major Professor: Dr. James A. Bennett
Department: Animal Science

Thirty-five range cows of various breeds were obtained for the study. Body measurements taken were live weight and hip height and all cows were condition scored for level of fatness. The cows were slaughtered and the following morning several carcass measurements were taken and the plate was removed from the left side. These plates were boned and the remaining flesh ground for chemical analysis of percent carcass fat. Regression equations were calculated for estimating percent carcass fat from condition score, weight:height ratio and hip height ($R^2=.765$). However, condition score alone is the single best estimator for percent carcass fat ($R^2=.759$).

INTRODUCTION

Beef producers in the United States must continuously deal with increasing competition for the consumer's dollar. They must face increased production efficiency from other meat producers, especially poultry and swine, and from non-meat food producers as well. However, there are other factors which have affected the consumption of beef that must be considered. Mainly, these have involved changes in consumer preferences.

Poultry producers, and to a lesser degree pork producers, have increased efficiency of meat production. The resulting lower cost of meat from these two species is presently having a significant detrimental economic impact on beef producers. Examination of relative prices and per capita consumption levels of different type meats indicates the degree and extent of competition from poultry and pork. Fifteen years ago, the retail price of pork was 82% that of beef and the retail price of poultry was 48% that of beef. Averages taken over the past three years show pork selling at 62% the retail price of beef, and poultry at 32%. Since poultry and pork producers have remained in production, these lower prices indicate an increase in production efficiency. The production of poultry alone has more than doubled over the last 20 years.

Technology has also more than doubled the yield of crops grown on the same amount of acreage in the last 30 years. Some of these crops, for example soybeans, are finding their way to the consumer as a meat substitute. More recently microbiologists have developed methods of harvesting high quality proteins from bacteria, another potential future competitor for the beef industry.

Another factor that needs cattlemen's attention is changes in consumer demands. Today, consumers are concerned about their caloric intake and the effect of excess intake upon their appearance and health. In the supermarket, beef is no longer accepted with the 30 to 35% fat that was common twenty-five years ago. Beef with 20 to 25% is much more acceptable to the consumer.

To deal with changing demands of consumers and increased competition from other food producers, cattlemen need to utilize research better to become more efficient in producing beef. One direction that research has led cattlemen, in view of increasing production efficiency, is selecting cattle that have a high rate of gain. Through selection and crossbreeding with exotic breeds of cattle, cattlemen have identified strains of cattle that have a high rate of gain and a greater weight for age. However, higher growth rate has increased mature size of cattle.

These larger, faster gaining cattle are more nearly meeting consumer demand for carcass size and fat content and are performing well in the feedlot. However, their

influence on overall efficiency of the cattle industry has not been determined. Size of brood cow has significant economic importance. The cost of maintaining the breeding female is the major cost in a cow-calf operation. Larger cows require more feed per head for maintenance than smaller cows. Unless pounds of calf weaned per cow more than offsets this increased feed demand, a decrease in efficiency of production has occurred.

More recently, nutritionists have been analyzing feeding regimens in an effort to increase production efficiencies. It has been well documented that all cattle have a maximum percent daily protein growth. That is, all animals have a maximum capability for daily protein growth which is a percentage of their mature body size. Energy consumed in excess of energy needed for protein growth is deposited as fat. Cattle fed diets with lower energy levels contain less carcass fat than cattle fed diets with high energy levels. Within a given type of beef animal, the same size carcass with less fat could be produced by feeding the animal enough energy for protein growth during its growth cycle. Then, when the animal is near maturity, an increase in dietary energy will lay down enough fat to make the meat palatable to the consumer. It has also been suggested that these cattle can be fed roughage diets during their growth period and fed diets containing concentrates the last 50 days before going to market. This method of feeding cattle would produce a leaner carcass with

the same palatability, but can only be applied to certain biological types of cattle.

Large-type, post-weaning cattle need concentrates in their diets in order to reach maximum protein growth. This indicates that different type cattle have different nutritional niches which optimize their production efficiency. Different production niches also exist. In any given area, environmental variations such as forage species and climate determine an optimum size animal that will achieve maximum efficiency. Again, size of brood cow becomes important to emphasize. The heritability of mature weight is high and half of the inheritance for mature weight of an offspring will be contributed from the dam. Mature size of the cow will have a significant influence on the mature size of her offspring.

It is important to determine cow size and its influence in order to maximize production efficiency on the cow-calf operation. Presently, there is no method of precisely measuring the functional size of the brood cow. Weight has traditionally been used as an indicator, but it has shortcomings. In brood cows, weight can vary with fill of digestive tract, stage of pregnancy and percent fat in the animal's body.

Variations in digestive fill can be standardized satisfactorily by keeping cattle off feed and water for a prescribed period of time. Weight variations associated with pregnancy can be minimized by weighing during early

pregnancy or by adjusting for weight of the fetus and associated tissues with adjustment factors. No simple adjustment factor is available to adjust weight of a cow for differences in fat content. Variations in body fat are closely related to quality and quantity of available forage, but they are also influenced by factors such as milk production.

Any adjustment factor that is developed must have an easy field application for range cows. Most range cows are rather wild and when confined struggle vigorously, making accurate body measurements difficult to obtain. The purpose of this study is to develop a method by which amount of fat can be measured accurately through field application without extensive restraint of the animal. If the amount of fat can be determined, then functional size can be determined.

LITERATURE REVIEW

Variability of Cow Size

At present there is wide variability in body size among and within commercial beef herds. Cartwright (1979) gives three plausible explanations. First, research indicates that there are no differences in feed efficiency among different size cows. There would, therefore, be no selection for any particular size if selection is based on feed efficiency. Second, environmental variations such as climate, feed resources, seasonal grazing and market preferences determine each production niche. Since production niches are heterogeneous, each would have an optimum size cow which would be most efficient. And third, dynamic and somewhat cyclic production conditions have caused a continuous variation in size preferences.

Dinkel and Brown (1978) have done research to determine differences in efficiency between different size cows. Their research indicates that larger cows do not convert feed more efficiently than smaller cows. They calculated a weaning weight efficiency on cows by the ratio of total digestible nutrient (TDN) intake of a cow for one year plus TDN intake of her calf until weaning, to weaning weight of the calf. This ratio determines kilograms (kg) of TDN required per kg of calf weaned. The weight of the cows in the experiment ranged from 360 kg to 578 kg. The efficiency ratio on all

cows in the experiment averaged 11.5 and ranged from 9 to 15.8, however, the smallest cow had an efficiency ratio of 12.6. The most efficient cow weighed 429 kg and the least efficient cow weighed 462 kg. Efficiency, measured by this study and under this environment, appears to be unrelated to body weight of cows.

Dickerson (1978) presents evidence to support the concept that optimum size of cow varies among different environmental niches. He concluded, for example, that under poor range conditions the genetically smaller cow is better able to forage and reproduce when compared to the genetically larger cow. In cold climates larger bodied animals may have advantages in tolerance to cold stress (Dickerson 1978). A smaller cow has more body surface area in proportion to her mass than the larger cow and, therefore, loses more body heat.

An example of cyclic production conditions, as referred to by Cartwright (1979), is the variation in weanling calf prices. The market for weanling calves has been variable with respect to relative prices per pound for light and heavy calves. When grain prices are high relative to the purchase cost per pound of calf, the cost per pound of feedlot gain is greater than the purchase cost per pound of calf and light weight calves are discriminated against. When grain prices are low relative to the purchase cost per pound of calf, the cost per pound of feedlot gain is less than the purchase cost per pound of calf and heavy weight

calves are discriminated against. Since large cows tend to wean heavier calves than smaller cows, fluctuating selling prices for large and small calves give little guidance to the producer as to which cow size would be optimum.

Definitions of Cow Size

Cow size has proven to be difficult to define and researchers do not agree on any one definition. Lush (1928) realized this problem when he wrote, "In the geometrical sense the animal body is of such a complicated shape that any one or few measurements could approximate a description of it in only the crudest way" (p. 54).

There are several different methods proposed to define cow size. The method most widely used by researchers is the single measurement of scale weight (Jeffery and Berg 1972; Johansson 1964; Gravir 1967). Cow size has been defined by Fitzhugh and Taylor (1971) as a complex character determined by body weight at a given degree of maturity for a given sex. Saunders and Cartwright (1979) define cow size as the average live weight of a mature cow with twenty-five percent of the weight made up of fat. Even though the latter two definitions are more detailed than the first, all have disadvantages.

A range cow may vary in weight as much as 200 pounds in one production year even though she has reached maturity. A large portion of the weight variation is caused by changes in physiological status such as pregnancy, but a substantial

portion of the variation is caused by the amount of fat in the animal's body (Berg and Butterfield 1976). Amount of fat is influenced by such environmental variations as seasonal changes in nutrient sources (Carpenter et al. 1978). Differences in fatness between animals can also result from genetic variations such as milking ability. For example, at weaning time poor milkers tend to be fatter than good milkers. If scale weight is used as a measure of cow size, two animals which are basically the same functional size may not appear so because of variations in amount of fat. And, since body weight varies with condition (amount of fat), it would not necessarily reflect physiological body size (Jeffery and Berg 1972). These workers have also pointed out that a population of animals would have to be in uniform condition before body weight could be used to compare body size among animals and that this is very unlikely.

Jeffery and Berg (1972) as well as Cartwright (1979) suggest another problem imposed by these definitions of cow size. Scale weight does not distinguish difference in degree of muscular development such as light or heavy muscled individuals.

Methods Used to Measure Cow Size

Researchers such as Carpenter et al. (1978) have used a combination of skeletal measurements to define size. In mature animals skeletal development is essentially a constant and is not markedly affected by environmental variations

(Jeffery and Berg 1972). However, there is general agreement by researchers that body measurements such as height and length reflect skeletal size of an animal and do not indicate differences in functional size (Brody et al. 1937; Davis et al. 1937; Guilbert and Gregory 1952; Johansson and Hildeman 1954; Kress et al. 1969; Yao et al. 1953). A good example of this can be illustrated by comparing research by two separate workers. In 1959, McDowell et al. reported the average wither height of mature Jersey cows to be 119.5 centimeters (cm) and the average heart girth circumference to be 159.8 cm. Earlier, Guilbert and Gregory (1952) measured mature Hereford cows and found the average girth circumference to be 192 cm and the average wither height to be 120 cm. These two breeds of cattle appear to be similar in size if their heights are compared but, very different in size if heart girths are compared. And, again researchers such as Jeffery and Berg (1972) and Cartwright (1979) agree that skeletal measurements such as height at hips and withers and body length do not determine differences in muscular development or degree of fatness.

Jeffery and Berg (1972) have studied the correlation between variables used to define cow body size. They found low correlations between linear body measurements and measurements which are correlated with scale weight. The correlation between wither-sacral height and heart girth was found to be .72. Of all the measurements studied, these workers found height to be least associated with body

weight. Kidwell (1955) studied the same measurements on fat Herefords and reported a correlation of .49 between wither height and heart girth and a correlation of .47 between body length and heart girth. Johansson (1964) also found low correlations between skeletal measurements and body weight. This research indicates that skeletal size is not highly correlated with muscular development or degree of fatness.

However, Touchberry (1951) extensively studied four body measurements, wither height, chest depth, body length and heart girth. He reported relatively high correlations between these four measurements which he classifies as measures of skeletal size and body weight which he classifies as a measure of amount of flesh. The correlation between body weight and wither height, chest depth and heart girth were .534, .665, .701 and .808, respectively. Touchberry (1951) concluded that there is strong evidence some genes have manifold effects which affect several quantitative characteristics. For example, a gene that would increase bone growth would likely increase growth of muscle tissue at the same time.

Carpenter et al. (1978) have applied a statistical procedure, principal components analysis, in an attempt to determine cow size. They concluded from their study that cow weight is an adequate measure of size. However, they reported that variations in fleshing condition was limited for the cows in their experiment.

Composition of Weight
Gain and Loss

As mentioned earlier, beef cows often undergo drastic changes in body weight in one production year. Recently, some research has been done on the composition of these weight changes. Schake and Riggs (1973) studied this in mature cows and found a consistent protein content with changes in amount of fat when changes in body weight occurred.

Other workers have studied the composition of weight gain in thin cull cows (Swingle et al. 1979). These cows were grouped and fed diets which varied in percent concentrates from 22% to 80%. They found the average weight gain to be 51% fat and 14% protein, indicating that there is some gain in percent muscle. However, these cows were fed diets high in concentrates not normally fed to range cows.

Growth of fat deposits during recovery after loss of body weight has been studied by Butterfield (1966). Eight steers which were semi-starved to cause weight loss, were fed to regain a live weight which they would have reached at 879 days of age under pasture conditions. He found that the proportion of total fat deposited intermuscularly and subcutaneously was the same during normal growth and weight recovery. They concluded that cattle have defined fattening patterns. That is, the deposition and depletion of fat between the different depots (intermuscular, subcutaneous,

intramuscular, or kidney fat) is determined by level of fatness. During weight loss, subcutaneous fat is depleted first and during weight gain other fat stores are replenished before subcutaneous fat.

Most of the weight variations in beef cows, other than that due to pregnancy, can be accounted for by changes in amount of fat. Variations in age, degree of muscular development, or live weight would not change fattening patterns. Since most fat is deposited subcutaneously as the total amount of fat increases, visual appraisal of amount of subcutaneous fat would give a good indication of the degree of fatness of an animal.

Measurement of Fat

Dairymen in Australia and New Zealand use condition scoring to estimate the fatness of cows in their herds. Gary et al. (1978) indicate that the amount of fat on dairy cows can be determined relatively accurately by visual condition scoring. These workers condition-scored nineteen cows of various body conditions and of various breeds. The actual percent fat of the cows was determined by chemical analysis of the ninth, tenth and eleventh rib section. The correlation between percent body fat and condition score was found to be .97.

Another method of determining amount of fat in a cow's body has been researched by Klosterman et al. (1968). They found that the weight:height ratio (weight in kg and height

in cm) of a beef cow is a good indicator of her body condition. Their research indicates that a cow in average condition had a ratio of 4. Cows with a ratio greater than 4 gained weight when fed maintenance rations determined by their body weight. A ratio of less than 4 indicates an animal is in thin condition. Klosterman et al. (1968) also studied the weight:height ratio of a cow and fat thickness determined by an ultrasonic machine and found a correlation of .51. The correlation between weight:height ratio and condition score was .89. In this study, weight:height ratio was not compared to the amount of fat determined by chemical analysis.

With the introduction of exotic breeds of cattle into the United States, it has become increasingly important to measure efficiency of different size cows. Many researchers have addressed this subject. However, often it is unclear how the authors determined cow size. For example, Olson et al. (1982) reported on the effects of cow size on cow productivity. They grouped cows into different size categories according to their scale weight. The four different categories were small (450.9 kg), medium (517.1 kg), large (566.8 kg) and very large (546.9 kg). The average weight:height ratio for each group as described by Klosterman et al. (1968) was 3.90, 4.27, 4.62 and 4.99 for small, medium, large and very large, respectively. A ratio greater than 4 indicates an animal is over-conditioned. Therefore, grouping animals into size categories by scale weight, as

was done by Olson et al. (1982), does not distinguish differences in degree of fatness and, therefore, does not adequately place animals into different functional size categories. It seems likely that the results of this experiment, which was to determine efficiency of different size cows, would be confounded by differences in amount of fat and be difficult to interpret.

MATERIALS AND METHODS

Animals

Thirty-five cows (Bos taurus) of either Hereford, Simmental x Hereford, Angus or Charolais x Angus breeding were obtained for the study. Fifteen of the cows came from Utah State University's experimental range herd and the others were purchased through public auctions at Cedar City, or Smithfield, Utah. All animals were transported to the University's Animal Science farm, located approximately seven miles south of Logan, Utah. After the cows had been rested and fed hay and given water for from 5 to 10 days, they were scored, measured, weighed and then sent to slaughter.

Data Collection: Cows

Scoring for condition was done on a scale of from 1 through 9 the day before slaughter. A set of photographs (figure 1), prepared by Dr. James A. Bennett of the Animal, Dairy and Veterinary Science Department of Utah State University, was used as an aid in condition scoring each cow. In these scores a condition score of 1 represents an animal that is extremely thin and a condition score of 9 represents an animal that is extremely fat.

Cows with a condition score of 1 have little flesh over the skeleton and the backbone is very prominent. Animals with condition scores of 2 and 3 also lack flesh

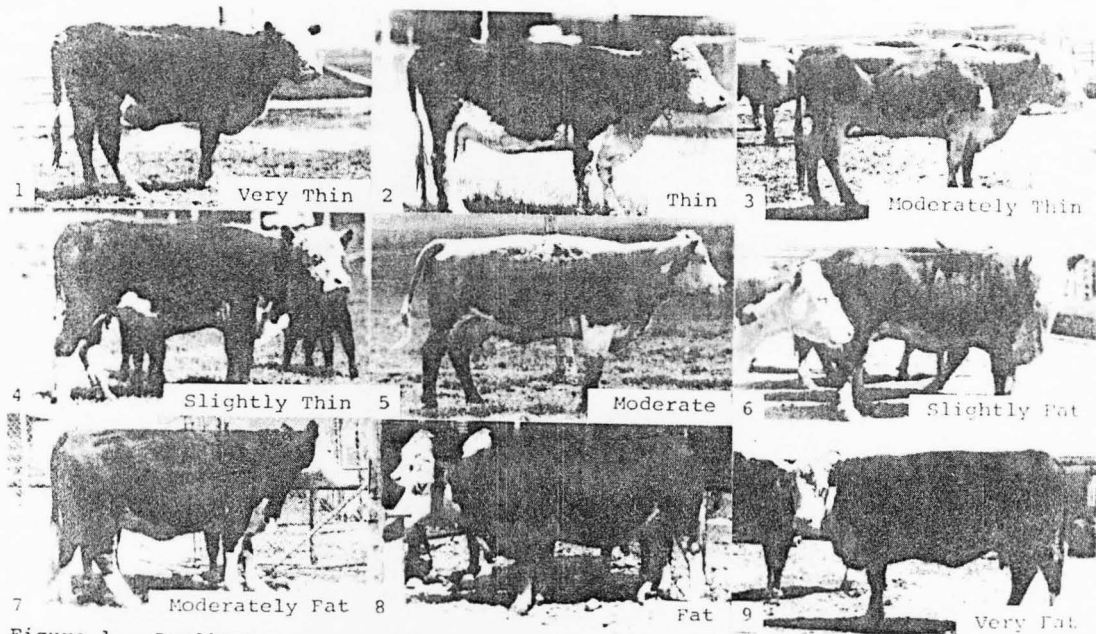


Figure 1. Condition scores of beef cows.

over the skeleton but the backbone area is less prominent. On cows scored in the midrange, the area around the tailhead becomes filled out and more fat is layed down over the back. Animals scoring in the upper range carry excessive fat around the tailhead and over the topline. The brisket and flank area also become filled out.

Hip height was determined by either of two methods. For the 15 cows obtained from Utah State University's herd, height measurements were marked off in inches on the back of a squeeze chute. As the cows were walked through the chute, their hip height was estimated. For the second method, a board, with lines marking height in inches from the ground, was hung from the fence. A height reading was taken on each cow as she stood in front of the board.

Live weight was taken after the animals has been off feed and water for 12 hours.

Data Collection: Carcasses

The cattle were assembled and processed in three sets. Five cows were slaughtered on June 8; 10 on June 16; and the remaining 20 cows on August 18, 1982. All cows were slaughtered at E. A. Miller and Sons Packing Company in Hyrum, Utah. The carcasses were chilled overnight and on the following morning the plate was removed from the left side of each carcass from the location as described by Orts (1962), (figure 2). Three carcasses were misplaced at the packing plant and were lost to the study. Other carcass measurements recorded were hot carcass weight, ribeye area,

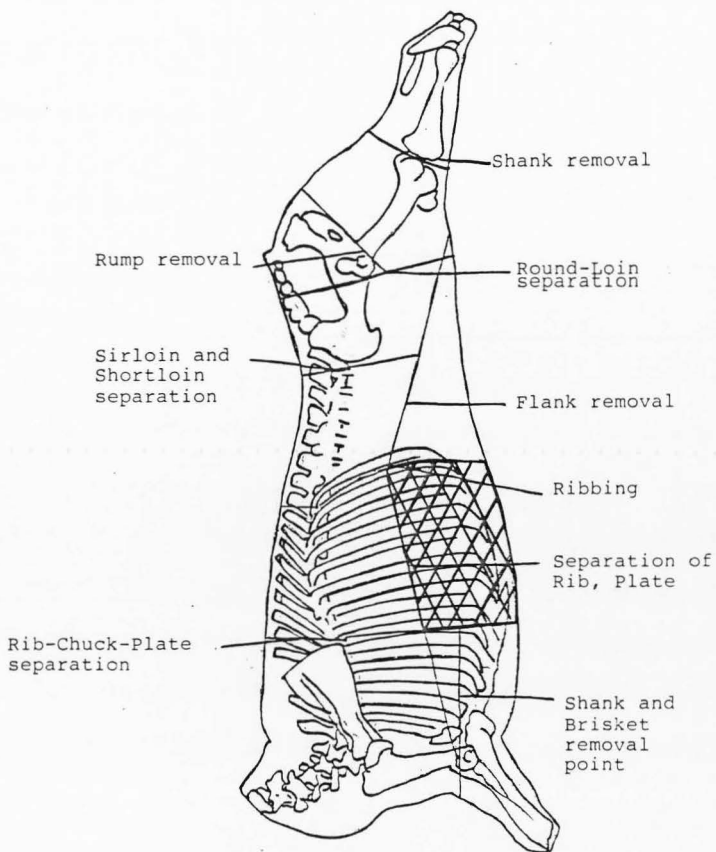


Figure 2. Portion of carcass removed as the plate is illustrated in crosshatch.

fat thickness over the 12th rib and maturity score. Cold carcass weight was estimated by subtracting 2% of the hot carcass weight.

Preparation and Chemical Analysis
of Carcass Samples

Each plate was boned and the flesh was coarsely ground and thoroughly mixed. A two pound random sample was then taken from the ground meat of each plate for later chemical analysis. The two pound samples were then frozen in the quick freeze unit at the Utah State University's Nutrition and Food Science Laboratory. All samples were kept in a frozen state in this freezer until August 25, 1982. On that date they were packed in insulated containers and shipped by air freight to the University of Arizona's Meat Laboratory, at Tucson, Arizona. Upon arrival there, they were placed in a freezer and kept in a frozen state until either September 13 or 15, 1982. Twenty of the samples were taken from the freezer on September 13, thawed and prepared for chemical analysis. The balance was similarly prepared on September 15.

The thawed samples were put through a fine grinder and thoroughly mixed until they were considered to be highly homogeneous. Two small subsamples were then withdrawn, each from a different part of the ground mass. Chemical determinations for total lipids were then made on these subsamples by chloroform-methanol extraction according to

the modified procedure of Ostrander and Dugan (1961) outlined by Wooten et al. (1979).

The values obtained for the two subsamples were then averaged and this average was considered to be the value for the plate from that animal. However, if the difference between the two values was greater than 3%, a third subsample was taken and another lipid determination was made. The two closest values, among the three values, were then averaged and that averaged value was accepted.

Determining Percent Carcass Fat

The percent fat in the animal's carcass was determined by applying an equation developed by Marchello et al. (1979). The equation is as follows: $\text{carcass lipid \%} = 2.2 + (.22 \times \text{cold carcass wt}) - (.07 \times \text{ribeye area}) + (.492 \times \text{12th rib fat thickness}) + (.639 \times \text{\% plate lipid})$.

Estimating Percent Body Fat

The percent carcass fat, derived by this equation, was then used to determine the percent body fat. This was done because condition score estimates the amount of body fat in the live animal while percent carcass fat is an estimate of the fat in the carcass.

Percent carcass fat was multiplied by the hot carcass weight to derive amount of fat in the carcass. Pounds of fat were then divided by the pounds of live weight to arrive at percent body fat.

Methods of Analysis

Procedures used for stepwise regression and correlation analyses were those according to Nie et al. (1975). Live weight, condition score, hip height and weight:height ratio were the independent variables used to estimate the dependent variable, either percent carcass fat or percent body fat. Simple correlations were calculated for all combinations of body measurements and percent fat.

RESULTS AND DISCUSSION

Animal Characteristics

The mean live weight for all animals in the experiment was 1,067, and the range was 680 to 1,540 pounds. The distribution between live weight and condition score is shown in figure 3. The range in maturity score on the carcasses was from C to E with most carcasses falling into the C and D categories. This indicates that the cows were largely 6 to 8 years old with a few older than eight years. Hip height ranged from 46 to 54.5 inches, with an average of 49.9 inches. Condition score averaged 4.66. Distribution of condition scores is shown in figure 3. Weight:height ratio averaged 3.81 and ranged from 2.41 to 5.15.

Statistical Analysis

Percentage carcass fat varied from an average low of 13.38 to a high average of 47.16 for condition scores of 1 and 9, respectively (table 1). Percentage body fat estimates showed somewhat similar variations. The method used to estimate percentage fat in this study does not take into account the channel (intrapelvic) and visceral fat. Therefore, an underestimate of total fat is obtained. However, Johnson et al. (1972) reported that the amount of fat deposited in these areas reaches a maximum early in fattening and increases very little as fattening progresses. This suggests that the error arising from omitting

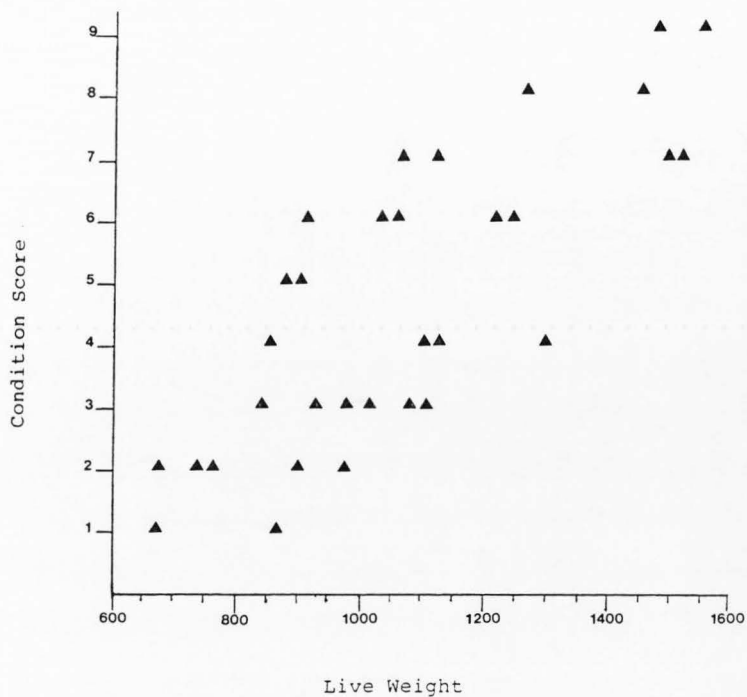


Figure 3. Distribution of live weight and condition scores.

Table 1. Distribution of condition scores and percent carcass fat.

Condition Score	Number of Cows	Mean Percent Carcass Fat
9	2	47.16
8	2	39.40
7	4	32.39
6	5	31.66
5	2	29.88
4	5	23.32
3	5	24.79
2	5	19.52
1	2	13.38

measuring the visceral and channel fat is rather small and would not influence comparative results materially, although the error would be proportionately larger on the thinner animals.

Simple correlation values were high for each measurement associated with all other measurements. All measured characteristics were significantly correlated to both percentage carcass fat and percentage body fat (table 2). Values were slightly higher for percentage carcass fat correlations than for percentage body fat, as would be expected, because of variations in dressing percentage.

The levels of the correlation values indicate that condition score has the highest correlation to percentage body fat (table 2). The value of .871 obtained in this

Table 2. Correlations between cow body measurements.

	% Body Fat	% Carcass Fat	Condition Score	Weight:Height Ratio	Hip Weight
Live Weight	.627	.713	.791	.989	.770
Hip Weight	.457	.519	.622	.668	
Weight: Height Ratio	.624	.712	.780		
Condition Score	.831	.871			

study, is a little lower than the .97 obtained by Gary et al. (1978) with dairy cows, but is higher than the .66 reported by Thompson et al. (1983) for Hereford and Angus x Hereford cows.

The results from the stepwise regression analyses are shown in table 3. Condition score is the single best estimator of fat levels in beef cows. These findings agree with Thompson's et al.(1983) conclusions that liner measurements are not superior to visual appraisal for estimating body composition in beef cows. Prediction equations for estimating percent body fat and carcass fat from condition score are shown in table 4.

The visual appraisal condition score was superior to weight:height ratio ($r=.871$ vs $r=.712$). Weight:height ratio is commonly used as an estimator of body condition (Klosterman et al. 1968). In this study, however, body weight alone was equal in accuracy to weight:height ratio

Table 3. Coefficients of determination from regression analyses using percent carcass fat as dependent variable.

Variable	R^2
Condition Score	.759
Condition Score, Weight:Height Ratio	.762
Condition Score, Weight:Height Ratio, Hip Height	.765

for estimating body condition. This does not necessarily imply that body weight would be equal to weight:height ratio, as an estimator under all conditions. It is obvious that if cows in a group have the same basic body size but vary in fatness, there will be a high correlation between body weight and body condition. In most populations, however, cows vary in basic size as well as in condition and these variations can be partially independent of each other. There could, then, be some heavy cows that are fatter than the lighter cows but, also some heavy cows may be thin while some light cows may be fat. Body weight, as the sole measure, would not then, accurately indicate body condition. The weight:height ratio would be more accurate under this situation.

Accuracy of Condition Score

The condition scores more accurately estimated percentage body fat at the extreme scores than in the midrange (table 5). The combination of the two highest

Table 4. Prediction equations for estimating percent fat from condition score.

$$\text{Percent Body Fat} = 4.622 + 2.1090x^a$$

$$\text{Percent Carcass Fat} = 11.957 + 3.3760x^a$$

x^a = condition score

with the two lowest scores gave the highest correlation ($r=.957$) of all combinations tested. Combinations carrying the three of four midrange values were markedly lower ($r=.597$ and $r=.529$, respectively) and were just at levels of significance.

Greater accuracy for scoring at the extremes, as compared to the midrange, could result from several reasons. The condition scores are discrete values and in a small sample, such as used in this test, there may have been more "liners" in the midrange groups than at the extremes. That is, more cows may have been borderline between scores in the midrange because of chance. The scoring method, however, required that each cow be given a definite score.

Some of the error may have, also, resulted from differences in fattening pattern over the range of increasing, or decreasing, fatness. Berg and Butterfield (1976) reported different fattening patterns between breeds. In the Shorthorn the fattening pattern is as follows: the amount of fat deposited intermuscularly and subcutaneously is constant until total amount of fat exceeds 30 kg. Then

Table 5. Correlation between percent body fat and condition score subsets.

Condition Score	r
9,8,2,1	.957
9,8,7,2,1	.906
9,8,7,3,2,1	.891
9,8,7,6,2,1	.840
9,8,7,6,5,2,1	.840
9,8,7,6,5,4,2,1	.843
9,8,7,6,5,4,3,2,1	.831
8,7,3,2	.815
7,6,5,4	.529
6,5,4	.597

the amount of fat deposited intermuscularly begins to decrease as the amount deposited subcutaneously begins to increase. Butterfield (1963) found the fattening patterns of the Hereford breed to be different from Shorthorns. During early stages of fattening in Herefords, most fat is deposited intermuscularly. As the total amount of body fat increases the amount of fat deposited intermuscularly decreases and the amount deposited subcutaneously increases. Fattening patterns of Angus were found to be similar to the Shorthorn (Berg and Butterfield 1976). However, in the Angus breed, the amount of fat deposited intermuscularly does not decrease as the amount

of total fat increases.

Berg and Butterfield (1976) have suggested that fat comes off in the reverse sequence to that in which it was deposited.

The fat that is observable when visually estimating the condition of an animal is largely subcutaneous fat. Differences in amount of intermuscular fat would be less evident on the live animal.

Because of the greater visibility of subcutaneous fat, fattening patterns in most breeds suggest that the animals having higher levels of fatness would more fully display their fatness. Visual scoring should, then, be more accurate on animals with high levels of fatness than on those with moderate levels.

Greater accuracy at the lower condition scores may occur because of the greater comparative influence of a unit quantity change in fat. For example, suppose two cows have similar body weights of 1,000 pounds and one has a condition score of 1 and the other of 5. The low scoring cow would have, approximately, 50 pounds of fat; and the cow scoring 5 approximately, 150 pounds of fat. If each cow should add 10 pounds of fat the thin cow has increased her fat by 20%. The cow scoring 5 has increased her fat by only 6.7%. This difference in relative change would likely be more visible and result in more accurate scoring at the lower levels.

This type of difference in relative change in percentage fat per unit change in quantity of fat, does not carry the same influence at the higher fat levels because , as pointed out above, as cows move above the midpoint in fatness, more of the fat is deposited subcutaneously where it is more visible.

APPLICATION OF RESULTS

Functional Size of Cow

A more exact measure of cow size influence upon productive and reproductive ability is needed. The high correlation between visual appraisal condition score and actual fat level in a cow's carcass indicates that visual appraisal can be useful in refining cow size estimates. Actual functional body size of beef cows can be more accurately estimated by the aid of this method than by live weight, hip height, or weight:height ratio. Also, condition appraisal can be easily done on range cows.

If the minimum desirable fat level is assumed to be approximately 25% carcass fat, as suggested by Saunders and Cartwright (1979), by applying the regression equation in table 4, body fat at this level is calculated to equate to a condition score of 3.7, or, in the nearest category, of 4. By applying the percent body fat equation (table 4) the percentage body fat values, as presented in table 6, can be derived. A conversion factor, k , can then be calculated for each condition score that will convert the actual live weight to a live weight that would contain 13.06% fat. This converts the live weight of a cow to a live weight at condition score 4.

This calculated weight can be considered to be a functional body size weight. Such weights have the body

Table 6. Percentage body fat and functional body size conversion factors for varying condition scores.

Condition Score	Body Fat / <u>1</u>	Functional Size Conversion Factor / <u>2</u>
	%	k
1	6.73	1.07
2	8.84	1.05
3	10.95	1.02
4	13.06	1.00
5	15.17	.98
6	17.28	.95
7	19.39	.93
8	21.49	.90
9	23.60	.88

/1 Derived by using regression formula from table 4.

/2 Multiplying actual live weight by k converts to body weight constituting 13.06% body fat as in condition score 4.

fat levels standardized at approximately 13%. These weights will be better comparative weights with which to evaluate productive and reproductive abilities of range cows of different sizes.

Relationship to Production

Current emphasis in cattle breeding is upon rate of gain, which is positively associated with frame size. Size is thus important because of its pervasive correlation with other traits. Correlation between mature size (as determined by scale weight) and postweaning rate of gain is estimated to be between .60 and .70. There is, also, a positive correlation between size and maturing rate (Cartwright 1979). Progeny of larger cows mature at an older age than progeny of smaller cows.

It is evident that larger size has both desirable and undesirable effects. The associated faster rate of gain is desirable but the greater mature size may not be desirable. Cows can be too large for a particular ecological niche (Cartwright 1979). Cows of all sizes cannot be equally able to obtain feed and flourish equally well under all feed, temperature and topographical situations.

Visually appraising cows for condition can increase accuracy in measuring basic, or functional cow size response, and identifying the interrelationships under all situations. The confounding effects of differences in fat level can be removed and the optimum size of cow

can be determined for the various niches with greater accuracy.

Relationship to Reproduction

It has been found that larger mature size and faster growth rates are rather highly related to size of offspring at birth (Brinks et al. 1962; Miguel et al. 1972). Large birth size is the major factor causing dystocia (Rice and Wiltbank 1972; Laster et al. 1973). Dystocia results in heavier perinatal losses (Laster and Gregory 1973; Smith et al. 1976; Jensen 1979). Dystocia also adversely affects subsequent reproductive ability (Brinks et al. 1973; Laster et al. 1973).

A more accurate measure of cow functional size will enable dystocia causes and consequences to be more specifically identified. This could lead to effective selection programs that could decrease the problems.

Visual condition scoring can be helpful as a management tool in aiding to optimize conception rates and calving intervals. Rearing offspring imposes great stress upon mammalian mothers. When environmental conditions are suboptimal gestation and lactation drain the mother's reserves and she loses body fat. Lactation is a particularly heavy drain. Clutton-Brock et al. (1982) stated that in red deer, male calves are heavier at birth, suckle longer and more frequently than female calves. This imposes extra drain on the mother and is reflected in the mother's

performance the following season. She is more apt to be barren, and if she does conceive she will conceive about 11 days later than mothers that reared female offspring.

Similar decreases in reproductive efficiency with associated fat depletion have been observed in range cows. Wiltbank (1981) reported that many thin range cows do not become pregnant, and among those that do become pregnant conception is often delayed.

Excessive fatness may also be detrimental to reproductive ability (O'Mary and Dyer 1978). These authors have presented theories on this subject. One theory is that excessive fatness may interfere in a mechanical way with the movement of ovum and sperm within the reproductive tract. A second theory is that an excessive amount of fat has some effect on hormone levels; it either absorbs certain reproductive hormones or blocks their synthesis. Or, an animal with a high percent body fat may have an increased body temperature which may interfere with reproduction.

By the application of visual score, such as used in this study, further studies could determine the minimum fat levels required to give satisfactory reproductive performance. Ranchers could learn easily how to evaluate the condition level of their cows by using these standards. They could then feed and manage their cows to obtain, or maintain, the desired level of fatness. To provide feed at levels that result in cows being markedly above, or below, optimum

level for a particular niche would be economically wasteful. Using such standards to evaluate cows would enable the rancher to avoid making economically costly feeding errors.

SUMMARY

Live weight, hip height, weight:height ratio, and a visually appraised condition score were evaluated on 35 beef cows to determine their accuracy for estimating percent body fat. Percent body fat was estimated from percent carcass fat which was derived by chemical determination of lipid percentage of the plate.

All body measurements were related to condition score and percent carcass fat or body fat ($P < .05$). Condition score was the best single estimator of percent carcass fat ($r = .871, .713, .712$ and $.519$) and percent body fat ($r = .831, .627, .624$ and $.457$) for condition score, live weight, weight:height ratio and hip height, respectively.

Combining the other measures with condition score increased accuracy of determination very little ($R^2 = .759$ vs $.765$) for condition score alone and condition score, hip height and live weight combined.

The accuracy of condition scoring was greater towards both extremes than near the midpoint. The differences in accuracy of estimating condition scores may be due to different fattening patterns of cattle breeds.

The results from this study can be applied to many areas of the commercial beef industry. A more exact measure of cow size influence upon productive and reproductive ability can be analysed. It is important to know the

amount of body fat. Range cows that are excessively thin or fat have lower reproductive rates.

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